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Doping effect of (Al and Cu) on photoconducting properties of chemically deposited CdS films

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Abstract : The doping effect of Al and Cu on the photoconducting properties of CdS film has been studied. CdS films have been chemically deposited with doping Al and Cu by 0.1 wt % each Their electrical and structural properties have been studied. The photoconducting studies of such films showed that the photoconductivity has been increased with 0.1 wt % Al doping and decreased with 0.1 wt % Cu doping.

Keywords : Photoconductivity, thin film, CdS

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Many investigations on the CdS films have been carried out to enhance its photoconducting properties by adding the impurities. Effect of trivalent impurities such as Al, In, Bi *etc.* which act as donors and monovalent impurities such as Cu, Na, Li which act as acceptors on the photoconducting and other properties have been studied [1–5]. It has been observed that 0.1 wt % (Al and Cu) doped CdS films give good results for photoconductivity [6–8].

In the present investigation, we have studied the effect of Al and Cu doping on the photoconducting properties of chemically deposited CdS thin film. It was observed that the CdS thin film deposited with Cd:S volume ratio as '5' gives the better results for photoconductivity [9], therefore CdS thin films with Cd:S volume ratio as '5' were prepared with doping of Al or Cu by 0.1 wt % each. The doping effect of Al and Cu on photoconductivity properties in air as well as in vacuum is reported.

The thin films of CdS have been prepared by chemical bath deposition [10]. Optical absorption of films, XRD and SEM studies were carried out to characterise the films.

For photoconductivity measurement the films of 0.5 cm width and 1 cm length were used. The ohmic contacts were made by silver paste. A 30 V dc power supply was used as a

voltage source and corresponding current change was measured by a current meter. The experiments were carried out both in air and vacuum (10^{-3} Torr) at room temperature (300 K).

A dc field of 30 volt was applied and the change in corresponding current was measured by a current meter. A 500W tungsten filament lamp was used as a light source.

Photoconducting rise and decay were studied in air as well as in vacuum at room temperature (300 K). The photoconducting rise and decay curves for pure and doped (Al and Cu) were recorded in air and in vacuum, with Omnscribe recorder (x/t mode).

The band gaps 'Eg' of the samples were estimated by the method used by Gover and Hodes [11] from optical transmission spectra of the doped (Al and Cu) and undoped films. The estimated band gaps 'Eg' from transmission spectra showed that there is no significant shift in 'Eg' with doping.

The crystalline nature of the pure and doped (Al and Cu) samples were studied by XRD. The films were slow scaned for the plane (002). The films are polycrystalline in nature..

The grain sizes for undoped and Al and Cu doped CdS evaluated from the XRD traces are 31.68 and 70 Å respectively. It was observed that the grain size is increased for Al and Cu doped samples, which can be attributed to the addition of impurities in the reaction bath. Since the photoconductivity of Al doped CdS is higher than that of Cu doped CdS, it is concluded that the photoconductivity in our samples is independent of grain size The undoped and doped (Al and Cu) samples with Cd:S volume ratio as '5' were studied with SEM and the same are shown in (Figures 1a, b, c). It is seen that the undoped film is polycrystalline with defined grain boundaries; the grain size is small and surface is not uniform. The SEM of Al (Figure 1b) and Cu (Figure 1c) doped films show the improved crystallinity. This supports the optical transmission and XRD studies.

The dark and photoconductivities of pure and doped (Al and Cu) CdS films were measured at room temperature (300 K) in air and in vacuum (10^{-3} Torr) at a light intensity of 10^3 lux are listed in Table 1. It was observed that 0.1 wt % Al doped CdS has higher conductivity than pure CdS. This can be explained as follows : when Al is doped in CdS, the Al goes in trivalent state and replaces divalent cadmium. During the substitution, there are two possibilities (1) substitution of Cd by Al and (2) possibility of Cd vacancies. Since Al and Cu are deposited simultaneously there is less chance for forming Cd vacancies. The observations showed increase in photocurrent for Al doped film indicating the first possibility.

The 0.1 wt % Cu doped CdS film has lower conductivity than the pure CdS. This can be explained as : since Cu goes in monovalent state and replaces divalent cadmium; there are two possibilities, (1) substitution of Cd by Cu and (2) possibility of Cd vacancies. Since the observations showed decrease in photocurrent, indicating the possibility of forming Cd vacancies.

Plate 1

(a)

(b)

(c)

Figure 1. SEM micrograph of (a) pure CdS; (b) 0.1 wt % Al doped and (c) 0.1 wt % Cu doped CdS.

Table 1. Dark and photoconductivities of pure and doped (Al and Cu) samples in air and in vacuum (10^{-3} Torr) at light intensity of 10^3 lux at 300 K.

Sr. No.	Sample	In air			In vacuum (10^{-3} Torr)		
		Dark conductivity mho cm^{-1}	Photo conductivity moh cm^{-1}	L/D conductivity ratio	Dark conductivity moh cm^{-1}	Photo	L/D conductivity
1	Pure CdS with Cd : S as 5	$2.4*10^{-4}$	$2.65*10^{-4}$	1.2	$3.9*10^{-5}$	$4.4*10^{-4}$	11
2	CdS : Al	$9.2*10^{-5}$	$3.7*10^{-4}$	4	$6.1*10^{-5}$	$1.1*10^{-3}$	18
3	CdS : Cu	6.10^{-5}	$6.3*10^{-5}$	1.5	$1.8*10^{-5}$	$1*10^{-4}$	5

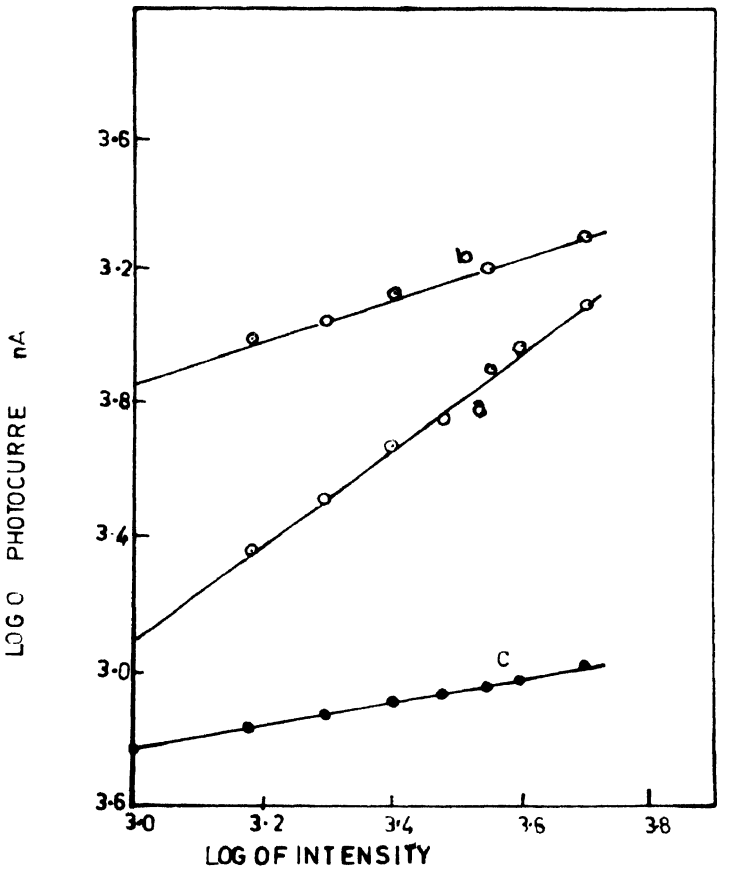

Figure 2. Log of photocurrent as function of light intensities (log–log scale) : (a) pure; (b) 0.1 wt % Al doped and (c) 0.1 wt % Cu doped.

The variation of photocurrent as a function of light intensity (log–log scale) for pure and doped (Al and Cu) films is shown in Figure 2. The samples exhibited sublinear photoconductivity as reported by Mangalam *et al* [12]. This means that the

photoexcitation is changing the number of free carriers which showed decrease in life time with increasing light intensity. The Figure 2 showed that at a fixed intensity, the change in number of free carriers is more for Al doped CdS and is less for Cu doped CdS than for pure CdS.

The rise and decay of the photoconductivity in freshly prepared pure and doped (Al and Cu) CdS was studied in air and in vacuum (10^{-3} Torr). The rise and decay times for the three samples were found to be in milliseconds in air. The rise times of doped (Al and Cu) were found to be lower than pure CdS. However, the observed decay is slow compared to those of pure CdS. The rise times in vacuum, for three samples were found to be in seconds.

The rise and decay of the photoconductivity for undoped and doped (Al and Cu) samples were studied in vacuum (10^{-3} Torr) at room temperature (300 K). The rise and decay curves for three successive cycles with rise time of 15 min and decay until the original dark current was reached are studied for pure, Al doped and Cu doped samples respectively, at a light intensity of 10^3 lux. All the curves exhibit similar nature and Figure 2 show such curves for Al doped CdS films. As all the samples were prepared by chemical bath deposition technique, oxygen molecules are assumed to be physically adsorbed on the surface of cadmium sulphide. They then become chemisorbed having captured conduction electron, which binds them to the surface. The energy levels of such bound electrons are sufficiently below the conduction band that, in the dark the rate of escape of electron from surface to the conduction band is negligible. Holes move to the surface under illumination and are captured by negatively charged oxygen molecules, giving neutral molecules which are weakly bound and can escape from the surface. This

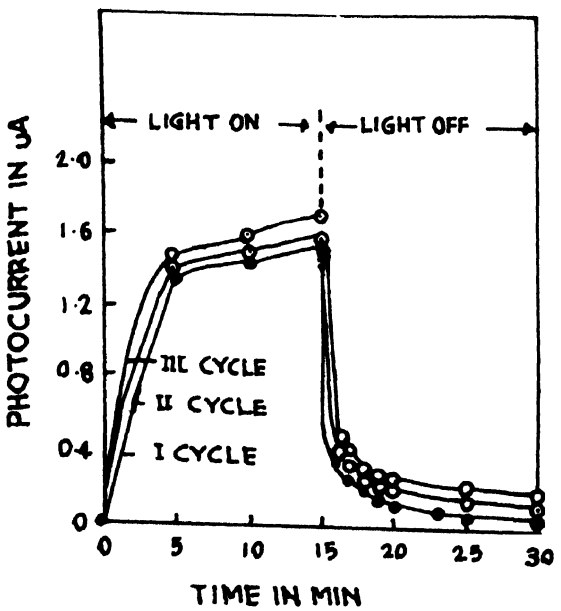

Figure 3. The rise and decay of the photocurrent with time for three successive cycles, for CdS : Al in vacuum.

process is responsible for the low values of both the dark current and photocurrent in the first cycle of excitation. In the second and successive cycles, a larger number of oxygen molecules are desorbed resulting in the faster rise time and higher photocurrent. Here, the rise and decay curves of photoconductivity are more pronounced for Al doped sample and less pronounced for Cu doped sample than that of pure CdS. This may be attributed to the availability of more electrons in Al doped CdS films and formation of Cd vacancies in the undoped CdS films.

It is concluded that the photoconductivity of chemically deposited CdS films is found to be increased with 0.1 wt % Al doping and decreased with 0.1 wt % Cu doping.

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